OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

# Remediation of PCBs at Superfund Sites

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## *Abstract*

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, was enacted by Congress on December 11, 1980, and provides Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. Sites contaminated with PCBs represent a significant number of the hazardous waste sites authorized for cleanup under CERCLA. This paper summarizes the overall decision-making process for developing cleanup plans for Superfund PCB sites. It discusses the Federal requirements that must be met in cleaning up Superfund PCB sites, remedial alternatives for PCB-contaminated National Priorities List (NPL) sites, and EPA guidance used in developing cleanup plans.

## I. *The Superfund Program*

### Regulatory Framework

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in response to the dangers posed by sudden or uncontrolled releases of hazardous substances, pollutants, or contaminants into the environment. This law, commonly called Superfund, requires the U.S. Environmental Protection Agency (EPA) to work with states and tribal governments to clean up hazardous waste sites across the United States.

CERCLA provides broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.[2] In particular, CERCLA: (1) established prohibitions and requirements concerning closed and abandoned hazardous waste sites, (2) provided for liability of persons responsible for releases of hazardous waste at these sites, and (3)

[1] Views expressed in "Remediation of PCBs at Superfund Sites" are those of the authors and do not represent the views of any Federal agency or department.

[2] References made to CERCLA throughout this document should be interpreted as meaning CERCLA, as amended by the 1986 Superfund Amendments Reauthorization Act (SARA). For more information about CERCLA, or to access the statute, see http://www.epa.gov/superfund/action/law/cercla.htm.

established a trust fund financed primarily by taxes on crude oil and 42 different commercial chemicals to provide for cleanup when no responsible party can be identified.

The National Oil and Hazardous Substances Pollution Contingency Plan, or simply the National Contingency Plan (NCP), is the Federal regulation that implements CERCLA.[3] It is the Federal government's blueprint for responding to discharges of oil and releases of hazardous substances, pollutants, and contaminants.

[3] The NCP can be found at Chapter 40, Part 300 in the Code of Federal Regulations (CFR).

**Steps in Superfund Cleanup**

CERCLA authorizes two types of response actions to address actual and potential releases at hazardous waste sites: removal actions and remedial actions. EPA uses removal actions at sites requiring immediate attention to prevent human contact with contaminants and to eliminate serious threats to human health or the environment. Removal actions may last a few days or up to five years, and may include providing clean drinking water to a neighborhood, removing hazardous materials from a site, or preventing contaminants from spreading. EPA evaluates the need for removal actions at a site prior to or during the Preliminary Assessment phase of the Superfund cleanup process (described below).

EPA uses remedial actions at sites where cleanup may take many years or decades (for example, groundwater cleanups). Remedial response actions permanently and significantly reduce the dangers associated with releases or threats of releases of hazardous substances that are serious, but not immediately life threatening. EPA conducts remedial actions at sites that qualify for listing on the National Priorities List (NPL), the Agency's list of sites that are priorities for long-term evaluation and remediation. Contamination at NPL sites may be addressed by removal actions and/or remedial actions, while contamination at non-NPL sites is addressed by removal actions.

The Superfund cleanup process begins with site discovery and notification to EPA of possible releases of hazardous substances. Once discovered, EPA enters sites into the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), the Agency's inventory of contaminated sites. EPA then evaluates and, if appropriate, addresses the potential for a release of hazardous substances from the site through the following steps in the Superfund cleanup process, which are discussed below:

- Preliminary Assessment/Site Inspection
- Hazard Ranking System Scoring
- National Priorities List Site Listing
- Remedial Investigation/Feasibility Study
- Record of Decision
- Remedial Action/Remedial Design
- Construction Completion
- Operation and Maintenance
- NPL Site Deletions

**Preliminary Assessment/Site Inspection.** EPA uses the Preliminary Assessment (PA) and Site Inspection (SI) to evaluate the potential risks to human health and the environment from hazardous waste sites. The PA is a limited-scope investigation performed on every CERCLIS site to collect readily available information about the site and the surrounding area. It is designed to distinguish, based on limited data, between sites that pose little or no threat to human health and the environment, and sites that may pose a threat and require further investigation. The PA also identifies sites requiring assessment for possible removal actions. If the PA results in a recommendation for further investigation, EPA performs an SI. The SI identifies sites that may enter the NPL site listing process and provides the data needed for the Hazard Ranking System (HRS) scoring procedure. The SI investigators typically collect environmental and waste samples to determine what hazardous substances are present at a site, whether they are being released to the environment, and if they have reached nearby targets.

**Hazard Ranking System Scoring.** EPA uses information collected during the PA and SI to calculate an HRS score that determines whether EPA will place a waste site on the NPL. The HRS assigns numerical values to factors that relate to risk conditions at a site, grouping the factors into three categories: (1) likelihood that a site has released or has the potential to release hazardous substances into the environment, (2) characteristics of the waste (e.g., toxicity and waste quantity), and (3) people or sensitive environments (targets) affected by the release. The overall HRS score is the sum of scores for four exposure pathways: ground water migration, surface water migration, soil exposure, and air migration. The site score can be relatively high even if only one pathway score is high. This is an important requirement for HRS scoring because some extremely dangerous sites pose threats through only one pathway. The cutoff HRS score for placing sites on the NPL is 28.5 out of a possible score of 100. However, a site score below 28.5 does not necessarily imply that the site poses no threat to human health or the environment. Such sites may be addressed by removal actions under CERCLA authority or by cleanup actions conducted by states or other authorities.

**National Priorities List Site Listing.** If a site meets listing requirements, EPA first proposes that it be added to the NPL in a *Federal Register* notice. EPA then accepts public comments on the site, responds to the comments, and places the site on the NPL if it continues to meet the listing requirements.

**Remedial Investigation/Feasibility Study.** After EPA lists a site on the NPL, site managers perform a Remedial Investigation/Feasibility Study (RI/FS) at the site. The RI serves as the mechanism for collecting data to characterize site conditions, determine the nature of the waste, assess risk to human health and the environment, and conduct treatability testing to evaluate the potential performance and cost of treatment technologies. The FS is the mechanism for the development, screening, and detailed evaluation of alternative remedial actions. Site managers conduct the RI and FS concurrently; data collected in the RI influence the development of remedial alternatives in the FS, which in turn affects the data needs and scope of treatability studies and additional field investigations.

**Record of Decision.** EPA creates a Record of Decision (ROD) for each site listed on the NPL from information generated during the RI/FS. The ROD is a public document that presents the remedial action selected by EPA to clean up a site on the NPL. It includes a site description and history, a summary of site risks and remedial action objectives, an analysis of possible remedial alternatives, and a discussion of the selected remedy.

**Remedial Design/Remedial Action.** The Remedial Design/Remedial Action (RD/RA) phases of Superfund site cleanup expand upon the provisions described in the ROD. The RD phase determines the technical specifications for cleanup remedies and technologies, while the RA involves the actual construction of remedies and implementation of site cleanup.

**Construction Completion.** When construction of the remedy is complete, EPA lists sites on the Construction Completion List (CCL). Generally, sites qualify when any necessary physical construction is complete (whether or not final cleanup levels or other requirements have been achieved).

**Operation and Maintenance.** Operation and maintenance (O&M) are activities required for certain remedies (e.g., ground water pump and treat or landfill capping) to maintain the effectiveness or the

integrity of a remedy. O&M measures are initiated after the remedy has been constructed and is determined to be operational and functional.

**NPL Site Deletions.** EPA may delete a site from the NPL if the Agency has carried out all phases of site cleanup and determined that no further response is required to protect human health or the environment. After the state and EPA concur that all appropriate response actions have been taken and no further action is required, EPA publishes a notice of intent to delete in the *Federal Register* and in a major newspaper that serves the communities near the site. EPA collects and responds to comments and, if the site continues to warrant deletion, publishes a deletion notice in the *Federal Register*.

### Status of Response Actions at Superfund Sites

Since passage of CERCLA in 1980, over 41,000 sites have been discovered and referred to EPA's Superfund program for PAs. As of December 2000, 11,578 of these sites have required further Federal attention and are tracked by the CERCLIS inventory (U.S. EPA, 2000b).[4] These sites have undergone either removal or remedial response actions, or are currently in the SI phase of Superfund cleanup. EPA has taken over 6,400 removal actions at CERCLIS sites, both at NPL and non-NPL sites.

As of January 2001, EPA has placed 1,458 of the 11,578 CERCLIS sites on the NPL since the inception of the Superfund program (U.S. EPA, 2000a). Of these sites, 229 have been deleted from the NPL, and 1,229 are currently listed on the NPL. Of the current NPL sites, cleanup construction is underway at 410 sites and construction has been completed at 759 sites. In addition, EPA is proposing listing 63 additional closed and abandoned hazardous waste sites on the NPL.[5]

## II. *PCB Contamination at Superfund Sites*

### What are PCBs?

Many Superfund sites are contaminated by polychlorinated biphenyls (PCBs). PCBs are a class of manufactured organic chemicals formed by the addition of chlorine ($C1_2$) to biphenyl ($C_{12}H_{10}$).[6] The PCB family consists of 209 individual compounds known as congeners. In general, PCBs are oily liquids whose color darkens and viscosity increases with rising chlorine content. Manufacturers typically produced PCBs as a complex mixture of congeners, through progressive chlorination of batches of biphenyl until they achieved a certain target percentage of chlorine by weight. PCB congeners with fewer chlorine atoms are relatively more soluble, more amenable to chemical and biological degradation, and less persistent in the environment than those with more chlorine atoms. While manufacturers sold commercial PCB mixtures under many names, mixtures known by the industrial trade name of "Aroclor" are the most common in the

[4] While CERCLIS initially included over 41,000 sites, EPA has since removed 29,500 sites not meriting further Federal attention from the CERCLIS database.

[5] Users can access the CERCLIS inventory, the list of NPL sites, and site-specific data for sites with cleanup decisions via the Superfund web site (http://www.epa.gov/superfund/sites).

[6] Biphenyl's dual-ring structure comprises two six-carbon benzene rings linked by a single carbon-carbon bond.

United States. Many commercial mixtures in the Aroclor series include a numerical identifier based on the percentage of chlorine (e.g., Aroclor 1254 contains 54 percent chlorine).

There are no known natural sources of PCBs. Until the cessation of production in 1977, more than 1.5 billion pounds of PCBs were manufactured in the U.S. They were used in hundreds of industrial and commercial applications due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties. In particular, manufacturers used PCBs as dielectric fluids in electrical transformers and capacitors; as hydraulic, lubricating, and heat transfer fluids; as plasticizers in paint; and as dye carriers in carbonless copy paper. Products containing PCBs include old fluorescent lighting fixtures, electrical appliances containing PCB capacitors, and hydraulic fluids.

Until 1977, PCBs entered the air, water, and soil as a result of their manufacture, use, and disposal. Today, PCB releases into the environment can occur because of illegal dumping of PCB wastes, leaks from electrical transformers containing PCBs, or releases from PCB-contaminated hazardous waste sites. PCBs are thermally stable and very persistent in the environment. PCB congeners tend to be hydrophobic; small quantities of PCBs may dissolve in water but most adhere to organic particles and sediments and therefore do not migrate as readily as more soluble contaminants. There are some site-specific characteristics that may have a bearing on the potential of PCBs to migrate. For example, PCBs in oil will be mobile if the oil itself is present in a volume large enough to physically move a significant distance from the source. Soil or sediment characteristics that affect the mobility of the PCBs include soil density, particle size distribution, moisture content, and permeability. Meteorological and chemical characteristics such as amount of precipitation, organic carbon content, and the presence of organic colloids also affect PCB mobility (Dávila et al., 1993). PCBs in water and sediment are likely to bioaccumulate in fish and marine mammals, and may reach levels thousands of times higher in the tissues of those organisms than the levels present in water or sediment.

### PCB Risk to Human Health

PCBs are one of the most widely studied environmental contaminants, and there have been many studies in animals and human populations to assess their potential carcinogenicity. EPA completed its first assessment of PCB carcinogenicity in 1988 based on Aroclor 1260 data (U.S. EPA, 1988b). In 1996, EPA completed a reassessment of PCB carcinogenicity at the direction of Congress (U.S. EPA, 1996a). In addition to Aroclor 1260, new studies provided data on Aroclors 1016, 1242, and 1254. Fifteen PCB experts peer reviewed EPA's cancer reassessment, including scientists from government, academia and industry. The peer reviewers concurred with EPA's conclusion that PCBs are probable human carcinogens.[7]

[7] EPA uses a weight-of-evidence approach to evaluate the potential carcinogenicity of environmental contaminants. This approach permits evaluation of the complete carcinogenicity database, and allows the results of individual studies to be viewed in the context of all of the other available studies. According to EPA's Integrated Risk Information System (IRIS), existing animal studies provide sufficient evidence of carcinogenicity, while existing human studies provide inadequate, though suggestive evidence of carcinogenicity. Based on these findings, IRIS classifies PCB mixtures as probable human carcinogens (U.S. EPA, 1997b).

EPA also evaluated the available data to determine the potential noncarcinogenic toxicity of PCBs. Extensive animal studies, including studies of non-human primates using environmentally relevant doses, provide clear evidence that PCBs have significant toxic effects in animals, including effects on the immune system, the reproductive system, the nervous system and the endocrine system. Because the body's regulation of these systems is complex and interrelated, PCBs can exert a multitude of serious adverse health effects. Based on studies of non-cancer health risks, as well as extensive information on the potential carcinogenicity of PCBs, EPA believes that the full body of scientific evidence supports a conclusion that PCBs constitute a danger to human health and wildlife.

Because of the stability of PCBs, many exposure routes are possible, including dermal exposure; ingestion of PCB-contaminated soil, sediment, water, and food; inhalation of ambient air contaminated with PCBs; and inhalation of PCB-contaminated fugitive dust. Activities with the potential to expose human receptors to PCBs include: using old fluorescent lighting fixtures and old appliances that may leak small amounts of PCBs into the air during operation; eating fish, meat and dairy products containing PCBs; directly contacting PCB-contaminated soil or sediment; drinking PCB-contaminated well water; and repairing or maintaining PCB transformers.

### Characteristics of Superfund Sites with PCB Contamination

Of the 1,229 Superfund sites currently on the NPL, PCBs have been detected at 357 sites (U.S. EPA, 2000b).[8] RODs have been issued for 307 of these sites. EPA has also deleted 52 PCB-contaminated sites from the NPL since the beginning of the Superfund program. It is difficult to generalize about the "typical" PCB-contaminated Superfund site; however, site information allows for the identification of some general trends.[9] PCBs may be one of several contaminants of concern at a site, often occurring with volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and metals. PCB contamination is most common at sites where PCB-containing products were manufactured or disposed. These sites may include: municipal or industrial landfills and disposal operations; battery salvage and recycling facilities; old railroads; and capacitor, transformer, paint, and paper manufacturing facilities. PCB-contaminated sites are therefore concentrated in industrial states. PCBs may be found in a variety of media, such as soil, ground water, sediment, surface water, waste, and debris. Users can retrieve site information, such as data on PCB contamination by media for sites with final cleanup plans, on the Superfund Sites web page (http://www.epa.gov/superfund/sites).

## III. *Development of Cleanup Levels*

When developing cleanup levels at a Superfund site, the site manager first identifies all applicable or relevant and appropriate requirements (ARARs, see definition below) for each contaminated medium. The final cleanup levels may be based on these ARARs; however, if no ARARs exist, or if multiple chemicals or exposure pathways are present at the site, a site-specific risk assessment may be necessary to establish cleanup levels that result in an excess cancer risk within the Superfund acceptable risk range of $10^{-4}$ to $10^{-}$

[8] Although PCBs have been detected at 357 NPL sites, detection does not necessarily imply that the levels of PCBs present at each of these sites constitute a significant risk to human health or the environment under CERCLA.

[9] Site-specific information is available on the Superfund web site (http://www.epa.gov/superfund/sites).

6.[10] The following section is not intended to be a comprehensive guide to determining risk-based cleanup levels. Rather, it focuses on the major ARARs that pertain specifically to PCB-contaminated sites and thus may serve as the basis for cleanup levels. In addition, while this section focuses on risks to human health, risks to ecological health may also be significant at PCB-contaminated sites. For more information about establishing human health and ecological risk-based cleanup levels, refer to Section V of this paper, which identifies EPA guidance to be considered in developing site-specific cleanup levels.

Response actions taken at Superfund sites must meet the requirements of CERCLA, which stipulates that the cleanup level for each contaminant be at least as stringent as any ARAR under Federal or state environmental law. ARARs may be either *applicable* or *relevant and appropriate. Applicable* requirements are those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. *Relevant and appropriate* requirements are those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited.[11]

"To-be-considered" (TBC) materials may also be helpful in determining the appropriate extent and manner of cleanup. TBCs are ordinances, advisories, guidance documents or other requirements that are not legally binding and do not have the status of ARARs. Section V presents a list of guidance documents that are potential TBCs.

Exhibit 1 presents a list of key EPA ARARs pertinent for developing PCB cleanup levels at Superfund sites. It is organized by environmental medium. This summary is not intended to be an exhaustive list of PCB-related ARARs; Superfund site managers may be required to address other regulations, especially state-specific regulations, that are not included here. Guidance on identifying other Federal or state-specific ARARs may be found in the *Compendium of CERCLA ARARs Fact Sheets and Directives* (U.S. EPA, 1991c).

[10] When a single ARAR for a specific chemical (or in some cases a group of chemicals) defines an acceptable level of exposure, compliance with the ARAR generally will be considered protective even if it is outside the risk range (unless there are extenuating circumstances, such as exposure to multiple contaminants or pathways) (U.S. EPA, 1997a).

[11] For more information about ARARs, the project manager should consult the *CERCLA Compliance with Other Laws Manual: Interim Final* and the *Compendium of CERCLA ARARs Fact Sheets and Directives* (U.S. EPA, 1988a and U.S. EPA, 1991c, respectively).

## Exhibit 1. Key ARARs for PCB-Contaminated Superfund Sites

| MEDIUM/ STATUTE | DESCRIPTION |
|---|---|
| **Waste** | |
| Toxic Substances Control Act (TSCA) | On June 29, 1998, EPA issued final amendments to the TSCA PCB Disposal Regulations (40 CFR Parts 750 and 761), which specify treatment, storage, and disposal requirements for PCB waste. The PCB wastes most commonly found at Superfund sites meet the TSCA definition of PCB remediation waste (examples are contaminated soil and sediment). The amended disposal regulations provide three options for cleaning up and disposing of PCB remediation waste, a self-implementing approach, a risk-based approach, and a performance-based approach. These requirements may be ARARs, depending on site-specific conditions. For additional information regarding the amended disposal regulations, see http://www.epa.gov/opptintr/pcb/pcbdisp.htm. |
| Resource Conservation and Recovery Act (RCRA) | The Land Disposal Restriction (LDR) Program protects public health and safety by establishing treatment standards for hazardous wastes before they can be disposed of in land disposal units. These treatment standards either specify that the waste be treated by a specified technology, or that they be treated by any technology as long as the concentration of hazardous constituents is below a certain level. These levels are called universal treatment standards (UTS) and are listed in 40 CFR Part 268.48. Separate restrictions apply to hazardous debris and soils, and are provided in 40 CFR 268.45 and 268.49, respectively. LDRs only apply to waste that is considered hazardous under RCRA. PCBs alone are not a RCRA hazardous waste; however, if PCBs are mixed with a RCRA hazardous waste, the PCBs may be subject to LDRs. For more information about the RCRA Land Disposal Restriction Program, see http://www.epa.gov/epaoswer/hazwaste/ldr/index.htm.<br><br>RCRA closure requirements for on-site treatment, storage, and disposal units are also potential ARARs. For more information, see the *CERCLA Compliance with Other Laws Manual* (U.S. EPA, 1988a). |
| **Soil** | |
| TSCA | As discussed above, TSCA is an ARAR for PCBs in soil. While the self-implementing approach under TSCA's amended disposal regulations provides specific soil cleanup standards for PCB remediation waste, Superfund typically conducts risk assessments, under the risk-based approach, to develop site-specific soil cleanup levels. A key Superfund guidance for developing site-specific cleanup levels is the 1990 *Guidance on Remedial Actions for Superfund Sites with PCB Contamination* (U.S. EPA, 1990). For a list of guidance documents pertinent to risk assessments, please refer to Section V.<br><br>The 1990 PCB Superfund guidance recommends risk-based preliminary remediation goals (PRGs) which are then used in developing final soil cleanup levels for the site.[1] The recommended PRGs for PCBs in soil are one ppm for residential soil and between 10 and 25 ppm PCBs for industrial soil. While EPA has developed important scientific information on PCBs since 1990, these PRGs are generally within EPA's acceptable risk range of $10^{-4}$ to $10^{-6}$. |
| **Air** | |
| | No potential ARARs related to specific cleanup levels for air exist. However, non-PCB-specific MACT emissions standards for hazardous air pollutants from hazardous waste incinerators may be potential ARARs if an incinerator is used at a PCB site. |

## Exhibit 1. Key ARARs for PCB-Contaminated Superfund Sites (continued)

| MEDIUM /STATUTE | DESCRIPTION |
|---|---|
| **Sediments** | |
| TSCA | As with soil, TSCA is also an ARAR for PCBs in sediments. Typically, as provided under the 1998 amended disposal regulations for the risk-based approach, site-specific risk assessments are performed when developing cleanup levels for PCBs in sediments at Superfund sites. For more information on developing site-specific cleanup levels for sediments at Superfund sites, please refer to http://www.epa.gov/opptintr/pcb/pcbdisp.htm and to Section V, which identifies EPA risk-assessment guidance. |
| **Water** | |
| Clean Water Act (CWA) | Section 304(a) of the CWA requires EPA to develop recommended water quality criteria based on the latest data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects. These criteria, often referred to as Section 304(a) criteria, provide guidance to states in adopting water quality standards that ultimately provide the basis for controlling discharges or releases of pollutants. States are required by Section 303 of the CWA to adopt water quality standards that are protective of the designated uses of their surface waters, and these standards must be approved by EPA.<br><br>EPA's National Recommended Water Quality Criteria for total PCBs based on human health effects of chronic exposure through drinking water and fish consumption is 0.00017 micrograms per liter. The aquatic life criteria for total PCBs based on chronic exposure are 0.014 micrograms per liter for fresh water and 0.03 micrograms per liter for salt water. CERCLA requires that remedial actions at Superfund sites meet these criteria, along with the state water quality standards that may be more stringent, where these criteria or standards are determined to be relevant and appropriate to the circumstances of the site. For additional information regarding water quality criteria and standards, see http://www.epa.gov/ ost/standards. |
| Safe Drinking Water Act (SDWA) | The SDWA requires the EPA to publish Maximum Contaminant Level Goals (MCLGs) for drinking water contaminants. EPA sets an MCLG at the concentration at which there are no known or anticipated adverse health effects associated with exposure to the contaminant, taking into account an adequate margin of safety and considering the effects on sensitive sub-populations. EPA established an MCLG of zero for PCBs, based on possible carcinogenicity (40 CFR 141). In addition, EPA must establish a Maximum Contaminant Level (MCL) as close to the MCLG as feasible or, if it is not economically or technically feasible to monitor the contaminant in drinking water, specify a treatment technology. MCLs for carcinogens are generally set at levels that reflect an excess cancer risk of $10^{-4}$ to $10^{-6}$ based on standard assumptions about daily water consumption and life expectancy.<br><br>Where such circumstances are relevant and appropriate to the site (e.g., water at the site is a potential source of drinking water), CERCLA specifies that Superfund remedies shall attain MCLGs established under the SDWA, unless the MCLG is set at zero. In such a case, the MCL should be used as the ARAR. The MCL established for PCBs in drinking water is 0.5 micrograms per liter (40 CFR 141). |

[1] PRGs are initial cleanup goals that are protective of human health and the environment and comply with ARARs.

## IV. *Remedies Selected at NPL Sites*

While site managers are working to characterize site contamination and develop appropriate cleanup levels during the remedial investigation (RI), they are also working on identifying potential remedies for meeting those cleanup levels as part of the feasibility study (FS). The FS involves the identification and detailed evaluation of potential remedial alternatives. This process begins with the formulation of viable alternatives, including identifying remedial action objectives, general response actions, volumes or area of media to be addressed, and potentially applicable technologies. Following a preliminary screening of alternatives, a reasonable number of appropriate alternatives undergoes a detailed analysis using the nine evaluation criteria in the NCP.[12] The result of this analysis is a preferred alternative, which is made available for public comment, and then the selected remedy is documented in the ROD.

As specified under the NCP, EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur (U.S. EPA, 1991b). The NCP indicates that EPA should use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable. Specific situations that may limit the use of treatment include: (1) treatment technologies are not technically feasible or are not available within a reasonable time frame, (2) the extraordinary volume of materials or complexity of a site make implementation of treatment technologies impracticable, (3) implementation of a treatment-based remedy would result in greater overall risk to human health and the environment due to risks posed to workers or surrounding community during implementation, or (4) severe effects across environmental media resulting from implementation would occur (U.S. EPA, 1991b). Containment measures are employed when contaminated material is disposed of on land, either on-site or at an off-site commercial facility.

Exhibit 2 presents descriptions of remedies that have been selected for PCB-contaminated soil and sediment at Superfund sites, grouped based on whether they involve treatment of PCB-contaminated material or constitute containment of PCBs. Brief descriptions of the technologies are provided below. For more information on these remedies, please consult EPA's *Engineering Issue - Technology Alternatives for the Remediation of PCB-Contaminated Soil and Sediment* (Dávila et. al., 1993). For information on which remedies have been selected at specific sites, please refer to the Superfund web site, http://www.epa.gov/superfund/sites/query/advquery.htm.

[12] For further information about the requirements for a feasibility study and the nine evaluation criteria, see *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents,* (US EPA, 1999).

## Exhibit 2. Remedies Used at PCB-Contaminated Superfund Sites

| REMEDY [1] | DESCRIPTION |
|---|---|
| **Treatment Remedies** | |
| Incineration | Waste is excavated and incinerated with the contaminated medium heated to temperatures exceeding 1,000°F in the presence of oxygen, resulting in the destruction of PCB compounds. Offgases are further treated by air pollution control equipment, such as scrubbers, that removes particulates and captures and neutralizes acid gases. |
| Thermal Desorption | Thermal desorption uses an indirect heat exchange to volatilize and separate organic compounds from a contaminated solid medium. This process is different from incineration, because the PCBs are not destroyed, merely vaporized. After volatilization, the contaminants are transferred from the solid using air, combustion gas, or an inert gas. The gas is then treated using desorption technology (e.g., wet scrubbers, baghouses). |
| Solidification/ Stabilization | Compared to incineration or thermal desorption, solidification/stabilization reduces the mobility of PCBs, rather than concentrate or destroy them. Stabilization involves the addition of a reagent to a waste to convert contaminants into a less soluble, mobile, or toxic form. Solidification uses a binding agent (e.g., Portland cement or asphalt) to encapsulate contaminants in solid material. Solidification creates a waste that is easier to handle and more resistant to water permeation, thus reducing contact between the contaminant and the transport medium. Solidification/stabilization remedial technologies use one or both of these techniques. |
| Bioremediation | Bioremediation optimizes the opportunity for bacteria in contaminated material to reduce complex organic compounds into simpler ones or to mineralize the compounds. The process is performed both in-situ, by enhancing environmental factors like nutrients or pH without disturbing the impacted media, or ex-situ, using above-grade land treatment, stirred-tank reactors, soil-heaping, or composting. |
| Solvent Extraction | This technology uses a solvent or blend of solvents to separate PCBs from the contaminated media, such as soil. The PCBs are not destroyed, however the volume of hazardous waste that must be treated and disposed is reduced. The contaminated material is usually excavated and run through an extractor, where solvent is added. The PCBs dissolve into the solvent, and the PCB/solvent mix subsequently is removed from the medium. The PCBs are then separated from the solvent by adsorption or by changing the pressure and/or temperature, and the solvent is recycled. The concentrated contaminant is typically incinerated. |
| Soil Washing | This process takes excavated material and mechanically mixes, washes, and rinses it with water. Some PCBs will either dissolve or become suspended in the wash solution, which is then treated as wastewater. PCBs that do not dissolve or become suspended in solution will preferentially bind to clay or silt. These finer particles may be separated from the coarser grained material, concentrating PCBs in a smaller volume of soil or sediment. |
| Vitrification | Vitrification uses heat to melt PCB-contaminated material, which, when it cools, forms a rigid, glassy product. The PCBs are destroyed by the heat used during the process, either by pyrolysis (in an oxygen-poor environment) or by oxidation (in an oxygen-rich environment). Vitrification can be performed either in-situ or ex-situ. |
| Chemical Dehalogenation | Chemical dehalogenation describes a group of technologies such as base-catalyzed decomposition (BCD) and alkaline metal hydroxide/polyethylene glycol (APEG) that remove halogen atoms from organic molecules. Generally, chemical dechlorination is applied to a condensate from thermal desorption, rather than directly to contaminated soil. |
| **Containment Remedies** | |

| | |
|---|---|
| Land Disposal | Depending on site conditions, PCB-contaminated material may either be left in place or excavated and disposed of in an on-site or off-site landfill. Material that is contained must pose a low threat to human and environmental health, and engineering or institutional controls may be used to ensure long-term protection against adverse health effects by restricting exposure to residual contamination. Controls may include caps, liners, leachate collection systems, ground water monitoring, surface water controls, and site security. |

[1] Remedies listed are those that have been selected to address PCB-contaminated soil and sediment.

## V. *Key Information Sources*

This section presents a listing of key guidance documents relevant to Superfund sites with PCB contamination as well as other EPA hazardous waste site-related guidance documents. Many of these guidance documents are potential "to-be-considered materials" (TBCs) for developing cleanup plans pertaining to Superfund PCB sites.[13] Exhibit 3 includes a complete reference and brief description for each document. It also includes the web site URL where users can obtain the document electronically. Most Superfund and PCB-related guidance documents are located at one of the following web pages:

- Superfund Publications: http://www.epa.gov/superfund/pubs.htm
- The National Environmental Publications Information System: http://www.epa.gov/clhtml/pubalpha.html (page image format only)

In addition, users may order hard copies of technical guidance documents through the U.S. Department of Commerce's National Technical Information Service (NTIS):

- NTIS, 5285 Port Royal Road, Springfield, VA 22161
  Phone: 1-800-553-6847 or (703) 605-6000; 8 a.m. - 6 p.m. EST, Monday-Friday
  Fax: (703) 605-6900; Web: http://www.ntis.gov/

Exhibit 4 provides EPA web sites where general information on the Superfund program and on PCBs can be obtained. It also describes several searchable web sites and databases where users may retrieve data about Superfund sites and PCBs. Although this paper focuses on risk to human health, ecological risk may also be a concern at PCB sites. Several web sites listed in Exhibit 4 address ecological risk. For example, the EPA Region 5 web site provides information about the ecological effects of PCBs, and the Superfund Risk Assessment program maintains a web site focusing on ecological risk assessment.

[13] As discussed in Section 3, TBCs are ordinances, advisories, guidance documents or other requirements that are not legally binding and do not have the status of ARARs.

## Exhibit 3. Key EPA Guidance Documents

| REFERENCE | DESCRIPTION |
|---|---|
| **Superfund PCB Sites** | |
| U.S. EPA, *Guidance on Remedial Actions for Superfund Sites with PCB Contamination*, EPA/540/G-90/007, August 1990. | This 1990 PCB Guidance describes the recommended approach for evaluating and remediating Superfund sites with PCB contamination. It provides preliminary remediation goals (PRGs) for various media that may be contaminated by PCBs. |
| **Developing Cleanup Levels** | |
| U.S. EPA, Office of Research and Development, *PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures*, EPA-600-P-96-001F, September 1996.<br>http://www.epa.gov/opptintr/pcb/pcb.pdf | The 1996 PCB cancer reassessment addresses PCB carcinogenicity and demonstrates how information on toxicity, disposition, and environmental processes can be used to evaluate health risks from PCB mixtures in the environment. |
| U.S. EPA, Office of Emergency and Remedial Response. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002. December 1989.<br>http://www.epa.gov/superfund/programs/risk/ragsa/index.htm | This document provides guidance on human health related risk assessment activities conducted during the baseline risk assessment, which is the first step of a RI/FS at a Superfund site. It includes topics such as data collection and evaluation, exposure and toxicity assessment, and risk characterization. |
| U.S. EPA, Office of Emergency and Remedial Response. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)*, Publication 9285.7-01B. December 1991.<br>http://www.epa.gov/superfund/programs/risk/ragsb/index.htm | This document provides guidance on using EPA toxicity values and exposure information to derive risk-based PRGs for use during analysis and selection of remedial alternatives. The development of PRGs builds on the site-specific baseline risk assessment conducted in accordance with *RAGS (Part A)*. |
| U.S. EPA, Office of Solid Waste and Emergency Response, *Soil Screening Guidance: User's Guide*, Publication 9355.4-23, July 1996.<br>http://www.epa.gov/superfund/resources/soil/index.htm | This document provides a methodology for site managers to calculate risk-based, site-specific soil screening levels (SSLs) for contaminants in soil that may be used to identify areas needing further investigation at NPL sites. |
| U.S. EPA, *CERCLA Compliance with Other Laws Manual: Interim Final*, EPA/540/G-89/006, August 1988. | This document provides guidance for complying with ARARs. |
| **Remedy Selection** | |
| U.S. EPA, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents*, EPA 540-R-98-031, July 1999.<br>http://www.epa.gov/superfund/resources/remedy/rods/index.htm | This document, commonly referred to as the "ROD Guidance," provides recommended formats and content for Superfund remedial action decision documents. It clarifies roles and responsibilities of stakeholders in developing decision documents and selecting remedies. |
| U.S. EPA, Office of Research and Development and Office of Solid Waste and Emergency Response, *Engineering Issue - Technology Alternatives for the Remediation of PCB-Contaminated Soil and Sediment*, EPA/540/S-93/506, October 1993. | This document provides information on established, demonstrated, and emerging technology alternatives for the remediation of soil and sediment at PCB-contaminated Superfund sites. |
| U.S. EPA, Office of Solid Waste and Emergency Response, *Rules of Thumb for Superfund Remedy Selection*, EPA/540/R-97/013, August 1997.<br>http://www.epa.gov/superfund/resources/rules/index.htm | This document describes key "Rules of Thumb" for Superfund remedy selection. Rules of Thumb are organized into three policy areas: risk assessment and management, remedial alternatives, and ground-water response actions. |

| | |
|---|---|
| U.S. EPA, Office of Solid Waste and Emergency Response, *Management of Remediation Waste Under RCRA, EPA530-F-98-026*, October 1998.<br><br>http://www.epa.gov/correctiveaction/resource/guidance/remwaste/pspd_mem.pdf | This memorandum consolidates existing gu and policies that most often affect remediat |

## Exhibit 4. Key EPA Web Sites

| URL | DESCRIPTION |
|---|---|
| http://www.epa.gov/superfund | The EPA Superfund Program comprehensive web site includes general information about the Superfund program, links to Superfund risk assessment information, and a Resource Center with links to Superfund-related information sources and guidance documents. |
| http://www.epa.gov/superfund/sites | The Superfund Sites web page provides a single point of entry for information about a specific Superfund site or group of sites, including location, type of contamination, site classification, and cleanup technologies. |
| http://www.epa.gov/pcb/ | EPA's PCB home page provides information on the Federal program for regulating PCBs under TSCA, with particular emphasis on regulatory activities within the Office of Pollution Prevention and Toxics. |
| http://www.epa.gov/grtlakes/toxteam/trt_pcbs.htm | This PCB web site hosted by EPA Region 5 includes technical information about PCB species identification, as well as information on PCB health/ecological effects and PCB remediation technologies. |
| http://www.epa.gov/superfund/programs/risk/tooleco.htm | EPA's Tools for Ecological Risk Assessment web site provides links to relevant guidance, policy, and tools for Superfund risk assessors. |
| http://map3.epa.gov/enviromapper/index.html | EnviroMapper generates maps of Superfund site location and status. |
| http://www.epa.gov/superfund/sites/query/advquery.htm | This web site allows users to search the CERCLIS database for the following types of information: Superfund site identifiers, geographic information, site assessment and cleanup activities, contaminants of concern, contaminated media, and site-related documents. |
| http://www.epa.gov/superfund/sites/rodsites/index.htm | This web site contains information about Superfund sites, including a database of archived sites for which no further remedial action is planned. Users may also obtain ROD abstracts and request CERCLIS reports or full-text RODs. |
| http://www.epa.gov/enviro/html/cerclis/cerclis_query.html | The EnviroFacts Warehouse Superfund Query Form provides users with another method to retrieve site data from the CERCLIS database. |
| http://www.epa.gov/iris/ | EPA's Integrated Risk Information System (IRIS) database contains information on PCB toxicity, including non-cancer effects. |

***References***


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U.S. EPA, Office of Emergency and Remedial Response. *Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS)*. December 11, 2000(b).

U.S. EPA. *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents*, EPA/540/R-98/031. July 1999.

U.S. EPA, Office of Solid Waste and Emergency Response. *Management of Remediation Waste Under RCRA*. EPA/530/F-98/026. October 1998.

U.S. EPA, Office of Solid Waste and Emergency Response. *Rules of Thumb for Superfund Remedy Selection*. EPA/540/R-97/013. August 1997(a).

U.S. EPA, Office of Research and Development. *Integrated Risk Information System (IRIS): Polychlorinated Biphenyls*. June 1997(b).

U.S. EPA, Office of Research and Development. *PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures*, EPA/600/P-96/001F. September 1996(a).

U.S. EPA, Office of Solid Waste and Emergency Response. *Soil Screening Guidance: User's Guide*, Publication 9355.4-23. July 1996(b).

U.S. EPA, Office of Emergency and Remedial Response. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)*, Publication 9285.7-01B. December 1991(a).

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U.S. EPA, Office of Emergency and Remedial Response. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002. December 1989.

U.S. EPA, Office of Emergency and Remedial Response. *CERCLA Compliance with Other Laws Manual;* Interim Final, EPA/540/G-89/006. August 1988(a).

U.S. EPA. *Drinking Water Criteria Document for Polychlorinated Biphenyls (PCBs)*, ECAO-CIN-414. 1988(b).